

CLAIMS

1. A system for detecting a rub in a turbomachine comprising:
 - a turbomachine;
 - sensors monitoring turbomachine conditions; and
 - an on site monitor in communication with the sensors, and loaded with instructions to implement a method for detecting a rub in the turbomachine.
2. The system of claim 1 further comprising a server in communication with the on site monitor via an internet.
3. A method for detecting a rub in a turbomachine, the method comprising:
 - monitoring turbomachine conditions; and
 - determining whether a rub is occurring.
4. A storage medium encoded with a machine-readable computer program code for detecting a rub in a turbomachine, the storage medium including instructions for causing a computer to implement a method comprising:
 - obtaining data indicating turbomachine conditions; and
 - determining whether a rub is occurring.

5. A method for detecting a rub in a turbomachine comprising:
 - a. obtaining data indicating shell metal temperature difference, steam inlet temperature and bearing vibration;
 - b. determining whether there has been an abnormal change in the steam inlet temperature;
 - c. determining whether a difference between the upper shell metal temperature and the lower shell metal temperature is above a specified limit;
 - d. determining whether there has been an abnormal change in vibration;
 - e. determining whether an abnormal change was found in any of queries b or c if there is an abnormal change in vibration; and
 - f. indicating possible rub if an abnormal change was found in any of queries b or c.
6. The method of claim 5 wherein the specified limit is about 50 degrees Fahrenheit.
7. The method of claim 5 wherein query d comprises:
 - calculating a current average of vibration amplitude over a current specified time;
 - calculating a past average of vibration amplitude over a past specified time;
 - calculating a difference between the current average and past average;
 - determining whether three consecutive differences are each greater than a specified differences limit; and
 - indicating a vibration if three consecutive differences are each greater than a specified limit.

8. The method of claim 7 wherein the current specified time is about from -60 seconds to 0 seconds, where 0 seconds is the current instantaneous time, and the previous specified time is from about -120 seconds to -60 seconds.

9. The method of claim 7 wherein query d further comprises:

calculating a current average of vibration over a specified average time;

determining whether three consecutive averages are above a specified limit;

and

indicating a vibration if it is determined that three consecutive averages are above a specified limit.

10. The method of claim 9 wherein the specified average time is about 10 seconds.

11. A method for detecting a rub in a turbomachine comprising:

obtaining data indicating rotor speed and vibration;

determining whether the rotor speed is near the first critical speed;

determining whether vibration amplitude is greater than a specified limit over a specified time, if the rotor speed is near the first critical speed; and

indicating a possible rub and high response at first critical, if vibration amplitude is greater than specified limit over a specified time.

12. A method for detecting a rub in a turbomachine comprising:
 - obtaining data indicating rotor speed and vibration;
 - determining whether the rotor speed is near the second critical speed;
 - determining whether vibration amplitude is greater than a specified limit over a specified time, if the rotor speed is near the first critical speed; and
 - indicating possible rub and high response at second critical, if vibration amplitude is greater than specified limit over a specified time.
13. A method for detecting a rub in a turbomachine comprising:
 - a. obtaining data indicating load and low pressure bearing vibration;
 - b. determining if there is an abnormal load;
 - c. indicating an abnormal load, if there is an abnormal load;
 - d. determining if the low pressure bearing vibration standard deviation is greater than specified limits;
 - e. indicating an unsteady overall vibration on low pressure bearing, if the low pressure bearing vibration standard deviation is greater than specified limits;
 - f. determining whether queries b and d were both answered in the affirmative; and
 - g. indicating a possible rub if both queries b and d were answered in the affirmative.

14. The method of claim 13 wherein query b comprises:
 - h. determining if the change in amplitude of load is larger than specified change limit over a specified time;
 - i. determining if the amplitude of load is larger than a specified amplitude limit; and
 - j. determining whether either query h or i were answered in the affirmative.

15. A method for detecting a rub in a turbomachine comprising:
 - a. obtaining data indicating condenser pressure and low pressure bearing vibration;
 - b. determining if there is an abnormal condenser pressure;
 - c. indicating an abnormal condenser pressure, if there is an abnormal condenser pressure;
 - d. determining if the low pressure bearing vibration standard deviation is greater than specified limits;
 - e. indicating an unsteady overall vibration on low pressure bearing, if the low pressure bearing vibration standard deviation is greater than specified limits;
 - f. determining whether queries b and d were both answered in the affirmative; and
 - g. indicating a possible rub if both queries b and d were answered in the affirmative.

16. The method of claim 15 wherein query b comprises:
 - h. determining if the change in amplitude of condenser pressure is larger than specified change limit over a specified time;
 - i. determining if the amplitude of condenser pressure is larger than a specified amplitude limit; and
 - j. determining whether either queries h or i were answered in the affirmative.
17. A method for detecting a rub in a turbomachine comprising:
 - a. obtaining data indicating vibration and differential expansion;
 - b. determining if there is abnormal vibration;
 - c. indicating an abnormal vibration, if there is abnormal vibration;
 - d. determining if there is a high differential expansion;
 - e. indicating a high differential expansion, if there is a high differential expansion;
 - f. determining whether both queries b and d were answered in the affirmative; and
 - g. indicating a possible rub if it is determined that both queries b and d were answered in the affirmative.

18. A method for detecting a rub in a turbomachine comprising:
 - a. obtaining data indicating vibration, eccentricity and load;
 - b. determining if there is abnormal vibration during transient;
 - c. indicating a vibration during transient if there is abnormal vibration during shutdown;
 - d. determining if there is abnormal vibration during a loaded stated;
 - e. determining whether there is a abnormal eccentricity amplitude or variation while on turning gear;
 - f. indicating an abnormal eccentricity while on turning gear, if there is a abnormal eccentricity amplitude or variation while on turning gear;
 - g. determining whether any of queries b or e was answered affirmatively;
 - h. indicating a possible rub during shutdown, if query b was answered affirmatively;
 - i. indicating an abnormal loaded vibration with eccentricity on turning gear; if query e was answered affirmatively; and
 - j. indicating a possible rub after abnormal eccentricity on turning gear, if query d was answered affirmatively.

19. A method for detecting a rub in a turbomachine comprising:
 - a. obtaining data indicating vibration, eccentricity and load;
 - b. determining if there is abnormal vibration during transient;
 - c. indicating a vibration during startup if there is abnormal vibration during transient;
 - d. determining if there is abnormal vibration during a loaded stated;
 - e. determining whether there is a abnormal eccentricity amplitude or variation while on turning gear;
 - f. indicating an abnormal eccentricity while on turning gear, if there is a abnormal eccentricity amplitude or variation while on turning gear;
 - g. determining whether any of queries b or e were answered affirmatively;
 - h. indicating a possible rub during startup, if query b was answered affirmatively;
 - i. indicating an abnormal loaded vibration with eccentricity on turning gear; if query e was answered affirmatively; and
 - j. indicating a possible rub after abnormal eccentricity on turning gear, if query d was answered affirmatively.

20. A method for detecting a rub in a turbomachine comprising:
 - obtaining data indicating rotor speed and vibration;
 - determining whether the turbomachine is in a speed hold, fixed speed no load, or steady state operation;
 - determining whether there is abnormal vibration variation, if the turbomachine is in a speed hold, fixed speed no load, or steady state operation; and
 - indicating a possible rub: sudden vibration change at steady speed, if there is abnormal vibration variation.

21. A method for detecting a rub in a turbomachine comprising:
 - a. obtaining data indicating eccentricity, vibration and axial displacement;
 - b. determining if there is high vibration amplitude;
 - c. determining if there is high vibration variation;
 - d. calculating a difference of a current mean of axial displacement and previous mean of axial displacement, and the standard deviation of each axial probe for a specific standard deviation time;
 - e. determining whether the absolute different between the current mean and previous mean is greater than a specified limit, X.
 - f. determining whether any standard deviation is greater than a specified limit, Limit1;
 - g. determining whether 2 out of 3 of the axial displacement standard deviations are greater than a specified limit, Limit2, if any standard deviation is greater than a specified limit, Limit1;
 - h. indicating a high standard deviation axial displacement if 2 out of 3 of the axial displacement standard deviations are greater than a specified limit;
 - i. determining whether either queries b or c were answered affirmatively;
 - j. determining whether there is a high eccentricity amplitude, if either queries b or c were answered affirmatively; and
 - k. indicating possible rub if there is a high eccentricity amplitude.

22. The method of claim 21, wherein the calculating of a current mean is calculated using axial displacement values collected from about -60 seconds to 0 seconds, where 0 seconds is the current instantaneous time, and wherein the calculating of the previous mean is calculated using axial displacement values collected from about -120 seconds to -60 seconds.

23. The method of claim 21, wherein the specific standard deviation time is about 30 seconds.

24. The method of claim 21, wherein X is about 2 mils.

25. The method of claim 21, wherein Limit1 is about 5 mils.

26. The method of claim 21, wherein Limit2 is about 5 mils.

27. A method for detecting a rub in a turbomachine comprising:
 - a. obtaining data indicating a turbomachine system
 - b. determining whether there is a rub associated with a sudden large shell temperature ramp;
 - c. determining whether there is a rub associated with a high response to first critical speed;
 - e. determining whether there is a rub associated with a high response to second critical speed;
 - f. determining whether there is a rub associated with an unsteady vibration affected by load;
 - g. determining whether there is a rub associated with an unsteady vibration affected by condenser pressure;
 - h. determining whether there is a rub associated with a vibration affected by a high differential expansion;
 - i. determining whether there is a rub associated with an abnormal eccentricity by a first method;
 - j. determining whether there is a rub associated with an abnormal eccentricity by a second method;
 - k. determining whether there is a rub associated with a vibration change at steady speed;
 - l. determining whether there is a rub associated with a high axial vibration standard deviation;
 - m. determining whether any of queries b through l were answered affirmatively; and

n. indicating a possible rub if any of queries b through l were answered affirmatively.

28. A storage medium encoded with a machine-readable computer program code for detecting a rub in a turbomachine, the storage medium including instructions for causing a computer to implement a method comprising:
- a. obtaining data indicating shell metal temperature difference, steam inlet temperature and bearing vibration;
 - b. determining whether there has been an abnormal change in the steam inlet temperature;
 - c. determining whether there has been an abnormal change in the upper shell temperature;
 - d. determining whether there has been an abnormal change in the lower shell temperature;
 - e. determining whether there has been an abnormal change in vibration;
 - f. determining whether a difference between the upper shell metal temperature and the lower shell metal temperature is above a specified limit;
 - g. determining whether an abnormal change was found in any of queries b, c, d or e, if the difference between the upper shell metal temperature and lower shell metal temperature is above a specified limit; and
 - h. indicating possible rub if an abnormal change was found in any of queries b, c, d or e.

29. The storage medium of claim 28 wherein the specified limit is about 50 degrees Fahrenheit.

30. The storage medium of claim 28 wherein query e comprises:
- calculating a current average of vibration amplitude over a current specified time;
 - calculating a past average of vibration amplitude over a past specified time;
 - calculating a difference between the current average and past average;
 - determining whether three consecutive differences are each greater than a specified differences limit; and
 - indicating a vibration if three consecutive differences are each greater than a specified limit.
31. The storage medium of claim 28 wherein the current specified time is about from -60 seconds to 0 seconds, where 0 seconds is the current instantaneous time, and the previous specified time is from about -120 seconds to -60 seconds.
32. The storage medium of claim 28 wherein query e further comprises:
- calculating a current average of vibration over a specified average time;
 - determining whether three consecutive averages are above a specified limit; and
 - indicating a vibration if it is determined that three consecutive averages are above a specified limit.
33. The storage medium of claim 32 wherein the specified average time is about 10 seconds.

34. A storage medium encoded with a machine-readable computer program code for detecting a rub in a turbomachine, the storage medium including instructions for causing a computer to implement a method comprising:

obtaining data indicating rotor speed and vibration;

determining whether the rotor speed is near the first critical speed;

determining whether vibration amplitude is greater than a specified limit over a specified time, if the rotor speed is near the first critical speed; and

indicating possible rub and high response at first critical, if vibration amplitude is greater than specified limit over a specified time.

35. A storage medium encoded with a machine-readable computer program code for detecting a rub in a turbomachine, the storage medium including instructions for causing a computer to implement a method comprising:

obtaining data indicating rotor speed and vibration;

determining whether the rotor speed is near the second critical speed;

determining whether vibration amplitude is greater than a specified limit over a specified time, if the rotor speed is near the first critical speed; and

indicating possible rub and high response at second critical, if vibration amplitude is greater than specified limit over a specified time.

36. A storage medium encoded with a machine-readable computer program code for detecting a rub in a turbomachine, the storage medium including instructions for causing a computer to implement a method comprising:
- a. obtaining data indicating load and low pressure bearing vibration;
 - b. determining if there is an abnormal load;
 - c. indicating an abnormal load, if there is an abnormal load;
 - d. determining if the low pressure bearing vibration standard deviation is greater than specified limits;
 - e. indicating an unsteady overall vibration on low pressure bearing, if the low pressure bearing vibration standard deviation is greater than specified limits;
 - f. determining whether queries b and d were both answered in the affirmative; and
 - g. indicating a possible rub if both queries b and d were answered in the affirmative.
37. The storage medium of claim 36 wherein query b comprises:
- h. determining if the change in amplitude of load is larger than specified change limit over a specified time;
 - i. determining if the amplitude of load is larger than a specified amplitude limit; and
 - j. determining whether either query h or i were answered in the affirmative.

38. A storage medium encoded with a machine-readable computer program code for detecting a rub in a turbomachine, the storage medium including instructions for causing a computer to implement a method comprising:
- a. obtaining data indicating condenser pressure and low pressure bearing vibration;
 - b. determining if there is an abnormal condenser pressure;
 - c. indicating an abnormal condenser pressure, if there is an abnormal condenser pressure;
 - d. determining if the low pressure bearing vibration standard deviation is greater than specified limits;
 - e. indicating an unsteady overall vibration on low pressure bearing, if the low pressure bearing vibration standard deviation is greater than specified limits;
 - f. determining whether queries b and d were both answered in the affirmative; and
 - g. indicating a possible rub if both queries b and d were answered in the affirmative.
39. The storage medium of claim 38 wherein query b comprises:
- h. determining if the change in amplitude of condenser pressure is larger than specified change limit over a specified time;
 - i. determining if the amplitude of condenser pressure is larger than a specified amplitude limit; and
 - j. determining whether either queries h or i were answered in the affirmative.

40. A storage medium encoded with a machine-readable computer program code for detecting a rub in a turbomachine, the storage medium including instructions for causing a computer to implement a method comprising:
- a. obtaining data indicating vibration and differential expansion;
 - b. determining if there is abnormal vibration;
 - c. indicating abnormal vibration, if there is abnormal vibration;
 - d. determining if there is a high differential expansion;
 - e. indicating a high differential expansion, if there is a high differential expansion;
 - f. determining whether both queries b and d were answered in the affirmative; and
 - g. indicating a possible rub if it is determined that both queries b and d were answered in the affirmative.

41. A storage medium encoded with a machine-readable computer program code for detecting a rub in a turbomachine, the storage medium including instructions for causing a computer to implement a method comprising:
- a. obtaining data indicating vibration, eccentricity and load;
 - b. determining if there is abnormal vibration during shutdown;
 - c. indicating a vibration during shutdown if there is abnormal vibration during shutdown;
 - d. determining if there is abnormal vibration during transient loading;
 - e. determining if there is abnormal vibration during a loaded stated;
 - f. determining whether there is a abnormal eccentricity amplitude or variation while on turning gear;
 - g. indicating an abnormal eccentricity while on turning gear, if there is a abnormal eccentricity amplitude or variation while on turning gear;
 - h. determining whether any of queries b, d or e were answered affirmatively;
 - i. indicating a possible rub during shutdown, if query b was answered affirmatively;
 - j. indicating an abnormal transient vibration with eccentricity on turning gear, if query d was answered affirmatively;
 - k. indicating an abnormal loaded vibration with eccentricity on turning gear; if query e was answered affirmatively; and
 - l. indicating a possible rub after abnormal eccentricity on turning gear, if either query d or e were answered affirmatively.

42. A storage medium encoded with a machine-readable computer program code for detecting a rub in a turbomachine, the storage medium including instructions for causing a computer to implement a method comprising:
- a. obtaining data indicating vibration, eccentricity and load;
 - b. determining if there is abnormal vibration during startup;
 - c. indicating a vibration during startup if there is abnormal vibration during startup;
 - d. determining if there is abnormal vibration during transient loading;
 - e. determining if there is abnormal vibration during a loaded stated;
 - f. determining whether there is a abnormal eccentricity amplitude or variation while on turning gear;
 - g. indicating an abnormal eccentricity while on turning gear, if there is a abnormal eccentricity amplitude or variation while on turning gear;
 - h. determining whether any of queries b, d or e were answered affirmatively;
 - i. indicating a possible rub during startup, if query b was answered affirmatively;
 - j. indicating an abnormal transient vibration with eccentricity on turning gear, if query d was answered affirmatively;
 - k. indicating an abnormal loaded vibration with eccentricity on turning gear; if query e was answered affirmatively; and
 - l. indicating a possible rub after abnormal eccentricity on turning gear, if either query d or e were answered affirmatively.

43. A storage medium encoded with a machine-readable computer program code for detecting a rub in a turbomachine, the storage medium including instructions for causing a computer to implement a method comprising:
- obtaining data indicating rotor speed and vibration;
 - determining whether the turbomachine is in a speed hold, fixed speed no load, or steady state operation;
 - determining whether there is abnormal vibration variation, if the turbomachine is in a speed hold, fixed speed no load, or steady state operation; and
 - indicating a possible rub: sudden vibration change at steady speed, if there is abnormal vibration variation.

44. A storage medium encoded with a machine-readable computer program code for detecting a rub in a turbomachine, the storage medium including instructions for causing a computer to implement a method comprising:
- a. obtaining data indicating eccentricity, vibration and axial displacement;
 - b. determining if there is high vibration amplitude;
 - c. determining if there is high vibration variation;
 - d. calculating a difference of a current mean of axial displacement and previous mean of axial displacement, and the standard deviation of each axial probe for a specific standard deviation time;
 - e. determining whether the absolute different between the current mean and previous mean is greater than a specified limit, X.
 - f. determining whether any standard deviation is greater than a specified limit, Limit1;
 - g. determining whether 2 out of 3 of the axial displacement standard deviations are greater than a specified limit, Limit2, if any standard deviation is greater than a specified limit, Limit1;
 - h. indicating a high standard deviation axial displacement if 2 out of 3 of the axial displacement standard deviations are greater than a specified limit;
 - i. determining whether either queries b or c were answered affirmatively;
 - j. determining whether there is a high eccentricity amplitude, if either queries b or c were answered affirmatively; and
 - k. indicating possible rub if there is a high eccentricity amplitude.

45. The storage medium of claim 44, wherein the calculating of a current mean is calculated using axial displacement values collected from about -60 seconds to 0 seconds, where 0 seconds is the current instantaneous time, and wherein the calculating of the previous mean is calculated using axial displacement values collected from about -120 seconds to -60 seconds.

46. The storage medium of claim 44, wherein the specific standard deviation time is about 30 seconds.

47. The storage medium of claim 44, wherein X is about 2 mils.

48. The storage medium of claim 44, wherein Limit1 is about 5 mils.

49. The storage medium of claim 44, wherein Limit2 is about 5 mils.

50. A storage medium encoded with a machine-readable computer program code for detecting a rub in a turbomachine, the storage medium including instructions for causing a computer to implement a method comprising:
- a. obtaining data indicating a turbomachine system
 - b. determining whether there is a rub associated with a sudden large shell temperature ramp;
 - c. determining whether there is a rub associated with a high response to first critical speed;
 - e. determining whether there is a rub associated with a high response to second critical speed;
 - f. determining whether there is a rub associated with an unsteady vibration affected by load;
 - g. determining whether there is a rub associated with an unsteady vibration affected by condenser pressure;
 - h. determining whether there is a rub associated with a vibration affected by a high differential expansion;
 - i. determining whether there is a rub associated with an abnormal eccentricity by a first method;
 - j. determining whether there is a rub associated with an abnormal eccentricity by a second method;
 - k. determining whether there is a rub associated with a vibration change at steady speed;
 - l. determining whether there is a rub associated with a high axial vibration standard deviation;

- m. determining whether any of queries b through l were answered affirmatively; and
- n. indicating a possible rub if any of queries b through l were answered affirmatively.